Adaptation-Guided retrieval for a diagnostic and repair help system dedicated to a pallets transfer.

Mohamed-Karim Haouchine, Brigitte Chebel-Morello, Noureddine Zerhouni

Adaptation-Guided Retrieval for a Diagnostic and Repair Help System Dedicated to a Pallets Transfer

Karim Haouchine[1], Brigitte Chebel-Morello[1], and Noureddine Zerhouni[1]

[1] Automatic Control and Micro-Mechatronic Systems Department
FEMTO-ST Institute –UMR CNRS 6174, France
24 rue Alain Savary, 25000 Besançon - France
{karim.haouchine, bmorello, zerhouni}@ens2m.fr

Abstract. In this paper, we describe a CBR approach for failure diagnosis of a pallets transfer. Adaptation phase is the key problem of the case-based reasoning system conception. This paper is a contribution to fill this gap in the equipments diagnostic and repair help. Retrieval step guided by adaptation is proposed, as a result similarity measures associated with an adaptation measure are proposed. These two measures will make it possible to select among the retrieved cases the most adaptable case. Then, an adaptation algorithm is proposed and will rely on a descriptors hierarchy, a context model as well as the dependences between problem and solution of the source cases. A feasibility study of the proposed algorithm is made on a real industrial diagnosis case. Three scenarios are treated in this study concerning various dependency relation values and belonging to the hierarchical classes of descriptors.

Keywords: case-based reasoning, adaptation, adaptation-guided retrieval, dependency relations, hierarchical model, context model, diagnosis.

1 Introduction

Adaptation is a complex step of case-based reasoning (CBR) and is most of the time designed for a specific application. Consequently, some authors [7] avoid the confrontation of this step and prefer to develop a retrieval part by considering that the wealth of the case-base can compensate the adaptation step [16]. However, other authors consider that adaptation is in the core of the CBR systems [3] and [10]. The first work on the adaptation was dedicated to a given application. To avoid this specificity, three axes were explored: 1) *AKA* (*Adaptation Knowledge Acquisition*) aims to define general principles of clarification of this adaptation in the studied field. A complete state of the art concerning these methods is in [10]. 2) *Catalogues of adaptation strategies which* apply in several domains are introduced in [12]. 3) *Unifying approaches* are studied in order to find propose a general adaptation model as proposed by Fuchs et al., in [6]. They propose a general adaptation algorithm independent of the applicability domain. The proposed adaptation approach is based on two main ideas. The first relates to the unification between the adaptation and retrieval steps (on a unified theory between adaptation and retrieval). The second is based on the dependency concept between the problem and solution of a solved case. The matching carried out at the time of the retrieval, combined with dependency relations between problems and solutions can adapt the solution to the target problem. In the case of our technical diagnostic study, these two ideas will be exploited. The first idea responds to the problem in selecting the cases to retrieval. Indeed, it is not the most similar case, when the similarity measure is a priori selected, which is the best candidate for the adaptation [3]. After presenting a state of art in the area, in the second paragraph, a specific formalization of the diagnosis case, based on two descriptor types is proposed. Thereafter a similarity measure is developed combined with an adaption measure definite to diagnosis system. For the adaptation step, the second idea will be used in determining dependency relations between problem and solution. These dependency relations between qualitative data are not trivial to implement. Three relationships are defined in the third paragraph, and are exploited to adapt a retrieval case, within an adaptation algorithm described in the fourth paragraph. Three standard diagnostic cases will illustrate the presented algorithm.

The proposed approach will be shown throughout this paper on a pallets transfer system Sormel as an industrial application. The feasibility of our approach will be studied in paragraph 4 on a limited number of 20 generic cases.

2 Retrieval guided by adaptation

Early work in the area is the AGR for Adaptation-Guided Retrieval [14] followed by work on the principle of the adaptation effort [3]. In fact, the proposed method will be underlined by two strong ideas: the first one relates to the unification between adaptation and retrieval step. Thus, this will allow a selection of the most adaptable cases which are not necessary the most similar [15]. Work of Leake in [8] addresses the adaptation effort concept and the impact of traditional semantic similarity measures on adaptation. Admittedly, the retrieved cases are “similar” to target problem, but sometimes difficult or impossible to adapt. Consequently, Leake takes into account the adaptation effort to the retrieval time in order to facilitate the adaptation step. This consideration is embodied by the inclusion of “adaptation cost” to the extent of similarity. Leake proposes two stages when assessing the similarity between the source cases and target problem. A first step of retrieval is followed by scheduling cases retrieved according to an adaptation cost.

In the field related to the diagnosis, there is a great diversity of work concerning the adaptation. Indeed, some systems such as $\text{Nodal}_{\text{CBR}}$ [4] and Gas Turbine Diagnostics [5] do not develop adaptation phase. While others, as FormTool [2], apply a transformational adaptation but has no knowledge model. Creek system [1] composed of a network of semantic knowledge is handled by three sub tasks namely activation, explanation and focus. Our system, as Creek, is based on the operating safety tools [11] to propose functional, dysfunctional or causality models. These models can be aggregated in a network of semantic knowledge as a Creek or be proposed in the case of our study, in the form of two models: hierarchical and context.

2.1 Retrieval Measure

The similarity metric depends on the case formalization. A case will have a formalization of object and will make it possible to define descriptors hierarchy containing as well the problems descriptors as the solution descriptors.

This model of components described in (Figure 1) is determined from the functional components analysis of the industrial plant. Every group of components is regrouped by functional classes, and constitutes a components' hierarchy which is common to the source problem descriptors *ds* and source solution *Ds*.

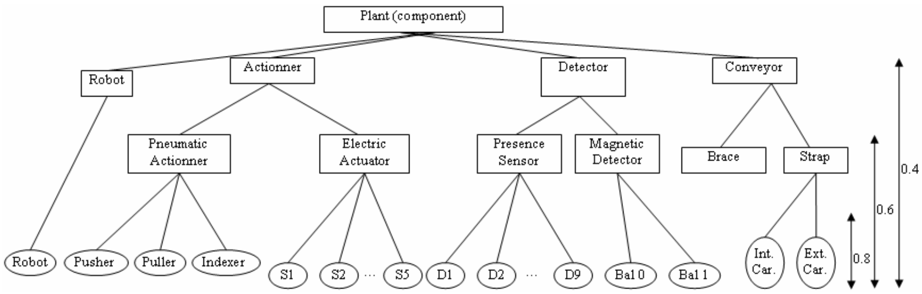

Fig. 1. The components hierarchy of the application

There will be two types of descriptors. The descriptors for an attribute like "ds_1 = zone" and "ds_2 = palette site" and descriptors associated with a value monitored by a sensor, resulting from a supervisor like "ds_3, ds_4 … ds_7" (Figure 2).

Qualitative values are associated with each attribute forming a partition attached to the attribute in question. Consequently, for each descriptor is stated: the problem descriptors will have three values: the component, its state and its functional mode: $ds_i = (d_{si}^{value}, d_{si}^{state}, d_{si}^{FM})$. A sample representative of four source cases is presented in figure 2.

	Problem																	Solution			
	Localization		Supervisor																		
	ds1	ds2	ds3			ds4			ds5			ds6			ds7			Ds1	Ds2	Ds2	Ds3
N° Case	Zone	Palette site	Prin Sen	State	FM	Pneu act	State	FM	Elec act	State	FM	Pre Sen	State	FM	Mag det	State	FM	Failure classe	Identification failure componant	Associated repair action	Failure zone
1	Internal ring	entry	D1	0	ab				S1	top	nor				Bal0	1	nor	Presence sensor	Shifted D1	To Replace	entry internal ring
4	Internal ring	exit	D8	1	ab	Pul	0	nor	S6	bot	nor				Bal1	0	nor	Presence sensor	Shifted D8	To Replace	exit internal ring
7	External ring	exit	D6	1	nor	Pul	0	nor	S5	top	ab	D7	0	nor	Bal1	1	nor	Electrical actuator	Blocked S5	To unblock	exit external ring
11	Puller zone	exit	D8	1	nor				S6	bot	nor	D9	0	nor	Bal1	1	nor	Pneumatic actionner	Blocked puller	To unblock	exit puller zone

Fig. 2. A part of the case-base of a pallets transfer

Let us consider the example of case 1. This case represents a problem on the "D1 detector". The localization part determines that there is a failure on the entry of the principal ring. Then, the supervisor part provides the components state implied in this place. The S1 stopper is in "high" position which has a "normal" functional mode. The balogh0 has value "1", which means that it must enter the working area so that it can be treated by a robot. Finally, the D1 sensor does not detect the presence of the pallet which is in "abnormal" mode. The solution part is made up of a class descriptor of failing component, of a descriptor identifying the failing component, of the repair action and finally of the failure zone.

The similarity measure is composed of four local similarities:

- For the value of d_{si}^{value}, which belongs to the hierarchical model of descriptors, φ^{value} is developed.

If $d_{si}^{value} = d_{ti}^{value}$ then $\varphi^{value} = 1$,

And if $d_{si}^{value} \neq d_{ti}^{value}$ then φ^{value} =0.8, φ^{value} = 0.6… or φ^{value} = 0

- For the descriptor value $d_{si}^{state}, \varphi^{state}$ is developed

If $d_{si}^{state} = d_{ti}^{state}$ then $\varphi^{state} = 1$, and if $d_{si}^{state} \neq d_{ti}^{state}$ then $\varphi^{state} = 0$

- For the functional mode defined in d_{si}^{FM}, φ^{FM} id developed

If $d_{si}^{FM} = d_{ti}^{FM}$ then $\varphi^{FM} = 1$, and if $d_{si}^{FM} \neq d_{ti}^{FM}$ then $\varphi^{FM} = 0$

- To take into account the information in descriptors, a local similarity $\varphi^{presence}$ is developed**.** $\varphi^{presence}$ =1, when the descriptor is indicated in the source case and $\varphi^{presence}$ =0, if not.

The global similarity measure (1) is obtained by aggregation of these functions on the whole set of descriptors. From this measure, a set of cases can be selected.

$$\text{Sim(source, target)} = \frac{\sum_{i=1}^{n} \varphi_i^{presence} . \varphi_i^{state} . \varphi_i^{value} . \varphi_i^{FM}}{\sum_{i}^{n} \varphi_i^{présence}} \quad \textbf{(1)}$$

Where *n*: represent the number of problem descriptors.

2.2 Adaptation Measure

The Adaptation Measure "A_M" (2) takes into account the source cases descriptors which are different from case target and will be linked to the class and to the functional mode compared to the solution descriptors.

$$A_M = \frac{\sum_{i=1}^{n} \varphi_i^{Class} \cdot \lambda_i}{\sum_{i=1}^{n} (\varphi_i^{F.M} + \varphi_i^{state}) . \varphi_i^{value}} \quad \textbf{(2)}$$

Where λ_i is the associated weight according to the functional mode

If FM=normal → $\lambda i = 2^0$; if FM= abnormal → $\lambda i = 2^2$; if FM= nor/ab → $\lambda i = 2^1$.

A weight is associated to the functional mode because this last is considered as being important in the determination of the failing component. The number of different descriptors is determined by the denominator in the equation (2). The retrieved source case having the greatest adaptation measure value among the retrieval source cases will be the candidate chosen for the adaptation step.

3 Adaptation Phase

The diagnosis is composed of two phases. A failure localization phase and a failing component identification phase [9]. The localization phase is done using a model which follows a specific magnitude. In our application, the course of a pallet will be followed. Using a contextual graph, as shown on figure 3 (left), components likely to be failing will be localised. An example of a context model concerning the descriptor "Ds_1" is shown on figure 3 (right). The context allows the localization of components problems and the selection of the right descriptors compared to all others. Therefore, these present components constitute the context in which the failing component is identified. A dependency relation is associated with these components.

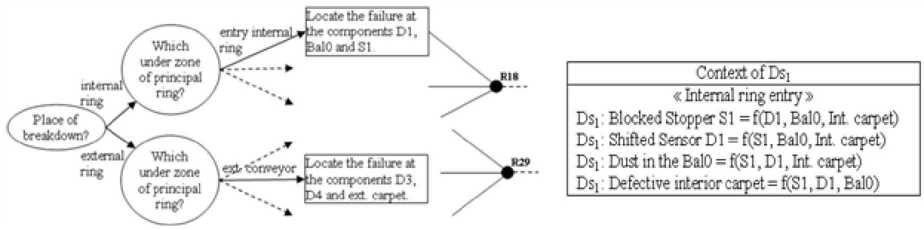

Fig. 3. Overview of the contextual graph part of the model equipment (left figure), a context model of "Ds1" descriptor (right figure)

3.1 Dependency Relations (DRij)

The influence of a descriptor problem "ds" on the descriptors solution "Ds" is expressed by a dependency relation. A dependency relation is a triplet (dsi, Dsj, DRij). DRij gives us the type of relationship between the problem and the solution to a given case. Three relation types are defined: DRij ⊂ {No relation; Low; High}.

DRij =High: there is a high dependency relation between ds_i descriptors strongly relevant[1] compared to Ds_j descriptor.

DRij =Low: there is a low dependency relation, i.e., the descriptors are connected thanks to the context which will be characterized by a contextual model

[1] A problem descriptor ds_i is strongly relevant compared to a solution descriptor Ds_j if there is pair of cases in the case base such as the cases are exclusively different by the value from the problem descriptor for two different values from the solution descriptor

DRij =No relation: there is independence between ds_i and Ds_j.
These dependency relations will be exploited in the adaptation algorithm.

3.2 Adaptation Algorithm

The algorithm (algorithm 1) relies on the context model, the descriptors hierarchical model and the dependency relations. The substitution's adaptation, by generalization and by specialization will be taken into account in the algorithm.

Input: Retrieval case (ds_i^{ret}[2], Ds_j^{ret}[3])
Output: descriptors solution of the adapted case Dt_j
1. Initialization step: create a list for each Ds_j^{ret} containing DR_{ji} values which are in relation to the source problem descriptors "ds_i"
2. Selection of the couple (DR_{ji}, Ds_j^{ret})
3. Application of the adaptation according to the RD values (DR = high, low, none) according to the descriptors hierarchical class and their positions according to their relations

   3.1. **If** (DR = high) **then** substitution of the source problem descriptor value after a generalization /specialization of the target problem descriptor value
   3.2. **If** (DR = low) **then**
   Find the source problem descriptor associated with the problem target descriptor corresponding to the same class as the solution source descriptor substitution
   Substitution of the new value of source solution descriptor by the corresponding value according to its class
   3.3. **If** (DR = none) **then** nothing to make
4. Allocation of the solution value to the concerned solution descriptor target

---

Algorithm 1. Adaptation Algorithm

This algorithm is conditioned by the solution descriptor class found at retrieval step. A substitution is made directly at the time of agreement between the class of the target case and retrieved source case. When there is divergence, a localization of the same class descriptor as the descriptor having an abnormal functional mode is given

[2] Retrieval descriptors problem
[3] Retrieval descriptors solution

using the context model. From this descriptor, the failing component is identified. When all DR values are equal to “no relation” then there is no adaptation.

4 Illustration of the Retrieval and adaptation steps

To illustrate how the adaptation algorithm works, a study is applied on an industrial plant which represents a Sormel flexible pallets transfer. The diagnostic cases modeling took a specific form, described in figure 2. The three examples which will be approached are illustrated in this section. For space constraints, only the first of the three examples will be detailed. For the others, the same reasoning is applied.

Example 1. “DR = High & same functional class”
Let the target case1 reflects a problem on the D9 detector (Figure 4). The source cases retrieval closest to this target case 1 provides two sources cases: the source case 4 and the source case 11 (Figure 2). The applied similarity threshold is 60%.

T1	Puller zone	exit	D8	0	nor				S6	bot	nor	D9	0	nor	Bal1	1	nor

Fig. 4. Problem part of the target case 1

- **Similarity Measure Calculation**

$$\varphi_i^{class} \quad \varphi_i^{state} \quad \varphi_i^{presence} \quad \varphi_i^{FM}$$

$$\text{Sim}(\text{srce}_1, \text{trgt}_1) = \frac{(1\times1)+(1\times1)+(0{,}8\times0\times1\times0)+(1\times1\times1\times1)+(0{,}8\times1\times1\times1)+(1\times1\times1\times1)}{6} = \mathbf{0{,}80}$$

Sim(srce_4, trgt_1)= 0,60

- **Adaptation Measure Calculation**

The second step consists in applying the adaptation measurement (A_M) by taking the weight λ_i = 1. This value considers that the abnormal functional mode is twice more important than the normal functional mode. There is only one descriptor different from the source case 11 compared to the case target 1, it is the “d_3” descriptor → (D8, 1, normal).

$$A_M(\text{srce}_1, \text{trgt}_1) = \frac{0.8\times2}{1} = 1{,}6 \quad A_M(\text{srce}_4, \text{trgt}_1) = \frac{(1\times4)+(1\times1)}{2} = \mathbf{2{,}5}$$

As for the source case 4, there are two different descriptors which are “d_3 and d_7”. According to the A_M values, the most easily adaptable case is the source case 4 because it has the greatest A_M value in spite of its stronger similarity value.

- **Adaptation Algorithm**

The nearest source case to this target case 1 is the source case 4. The dependency relations (RD_{14}) of the source case 4 are as follows:

Ds_4: Entry of internal ring = F^t (ds_1: puller zone and ds_2: exit)

Ds_2: Shifted D8 = F^t (ds_3: D8 = 1; RD_{32}=high, ds_4: Puller = 0; RD_{42}=low, ds_5: S6 = top; RD_{52} = low and ds_7: Bal1 = 0; RD_{72} = low)

It is important to note that the DR value of the pair (Ds_2, Ds_3) is "DR = high" and that the *D8* sensor which is shifted of the Ds_2 descriptor as well as the *D9* sensor of the descriptor dt_3 belong to the same class "presence sensor". Consequently:

- Substitution of the ds_3^{ret} by dt_3 = D9"
- The new value of ds_3^{ret} will affect the ds_2^{ret} descriptor value, which will get the value ds_2^{ret} = *shifted D8*
- Assignment of the new value of ds_2^{ret} to the target solution Dt_2

By applying the adaptation algorithm the solution is as follows: replacement of the sensor D9, which is shifted, is in the entry of the external ring.

Example 2. "DR = High & different functional classes"

Let the problem in the *external carpet* be represented by the target case 2 (Figure 5). The source case 7 (Figure 2) is more similar to the target case 2.

T2	External ring	ext conv	D4	0	nor				S3	bot	nor	D5	0	ab			

Fig. 5. Retrieval result of the similar case, in the case-base, to the target case 2

Sim(srce7, trgt2) = **0,76**, $A_M = \frac{0.6 \times 1}{1}$ = **0,60**

The DRs of the source case 7 are as follows:

Ds_4: internal conveyor of internal ring=F^t(ds_1: internal ring, ds_2: internal conveyor).

Ds_2: Blocked internal carpet=F^t(ds_3: Bal0=0; RD_{32}=low, ds_5: S6=bas; RD_{52}=low and ds_6: D8=0; RD_{62}=high).

The solution is to unblock the external carpet which is on the external ring.

Example 3. "DR = Low"

Let the problem in the *pusher* be represented by the target case 3 (Figure 6). The source case4 (Figure 2) is more similar to the target case 3.

T3	Pusher zone	entry	D1	0	nor	Push er	do not push	ab	S1	top	nor	D3	0	nor	Bal0	1	nor

Fig. 6. Retrieval result of the similar case, in the case-base, to the target case 3

Sim($srce_4$, $trgt_3$) = **0.85**, A_M = **0.** The source case 4 is the only retrieved case

Ds_4: Entry of puller zone=F^t (ds_1: puller zone and ds_2: entry)

Ds_2: Blocked puller=F^t (ds_3: D6=1; RD_{32}=low, ds_5: S5=haut; RD_{52}=low and ds_7: Bal1=1; RD_{72}=low)

The solution is to unblock the pusher in the entry of the pusher zone.

5 Evaluation

The validation of the adaptation algorithm requires a specific tests protocol. The case-base will be divided into 2 sets: 40% and 60% of cases. One will check in this occasion that the case-based reasoning can reason starting from a restricted number of cases, by taking support on the models and the adaptation step. For the case-base accuracy calculation, 40% of the case-base will be taken → 8 cases. Then, there is the appearance of the 60% of cases → 12 cases. These cases will be regarded as target cases, which will test the algorithm since one has the solution. The accuracy rate with and without adaptation will be calculated. The results show that the proposed method with adaptation selects the cases which are the best adaptable ones by obtaining 100% of accuracy (Figure 7). If the adaptation algorithm is powerful one can get a good performance concerning the CBR system applied to a limited number of cases.

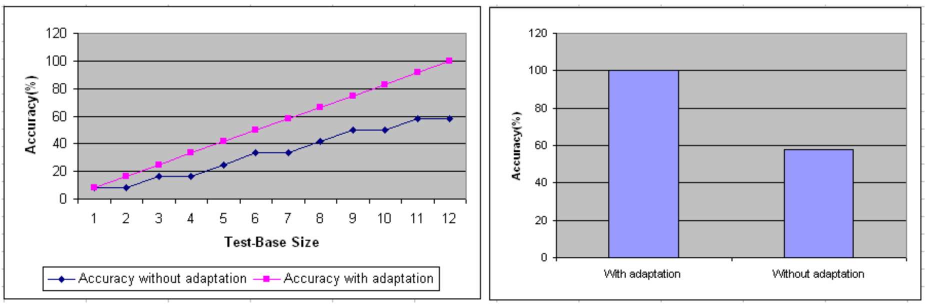

Fig. 7. Evolution of Accuracy following the number of cases in the test-base (left figure), Accuracy with and without adaptation (right figure)

However, one finds very bad results without the adaptation, only 58,1% accuracy rate with the retrieval step. To have a good results one must work on a complete data-set. Moreover the retrieval using only the similarity measure without adaptation do not select the cases which are the best adaptable ones (in particular concerning their classes). These results also show that the cases in the case-base belonging to different classes overlap and that the most adaptable is not necessarily the most similar.

6 Conclusions and Future Work

Within the study framework on technical diagnostic and repair help system, a case-based reasoning system has been proposed with the deployment of the different steps. The case-based reasoning system has been set up to apply to industrial systems supervising certain data and more specifically to a pallets transfer system. It comprises a formalization of object of the cases, associated to descriptors hierarchical model common to the problem and solution descriptors of the case-base cases and a model relating to the application context. All steps depend on the cases formalization and the associated knowledge models. Our previous studies have enabled us to formalize the case of a pallets transfer system. This formalization is adapted to our method. Modeling will influence the proposed similarity measure as well as the adaptation measure that are proposed. This last measure is directly related to the functional mode of the supervised components (an attribute specific to the descriptor). The developed retrieval step is guided by the adaptation using the conjunction of similarity and adaptation measures. This conjunction makes it possible to select among the retrieved cases which one is the most adaptable. The adaptation step, will exploit the dependency relations between the problem and solution. These dependency relations will be given either by selection of relevant descriptor or by using a context model between the various failures which can appear in an industrial plant. The adaptive algorithm detects three scenarios and proposes associated actions with each case.

The proposed case-based reasoning system for a specific application type must be generalized. The applied adaptation algorithm to detect the appearance of one failure at the same time will be studied within the multi faults framework.

References

1. Aamodt, A.: Knowledge-Intensive Case-Based Reasoning and Sustained Learning, Proc. of the 9th European Conference on Artificial Intelligence, ECCBR'04, pp.1-15, (2004).
2. Cheetham, W., Graf, J.: Case-Based Reasoning in Color Matching., the 2nd Second International Conference on CBR Research and Development, pp.1-12, vol. 1266, (1997).
3. Cordier, A., Fuchs, B., Mille, A.: Engineering and Learning of Adaptation Knowledge in Case-Based Reasoning, 15th IC on EKAW'06, 303-317, Czech Republic (2006).
4. Cunningham, P., Smyth, B.: A Comparison of Model-Based and Incremental Case-Based Approaches to Electronic Fault Diagnosis, AAAI , Seattle, USA, (1994).
5. Devaney, M., Cheetham., B.: Case-Based Reasoning for Gas Turbine Diagnostics, In 18th International FLAIRS Conference (FLAIRS-05), (2005).
6. Fuchs, B., Lieber, J., Mille, A., Napoli, A.: An Algorithm for Adaptation in Case-Based Reasoning. *In Proceedings of the 14th ECAI*, Berlin, Germany, p. 45–49, (2000).
7. Kasif, S., Salzberg, S., Waltz, D., Rachlin, J., Aha, D.: Towards a Framework for Memory-Based Reasoning. *NECI Technical Report,* pages 95-132, (1995).
8. Leake, D.B., Kinley, A. and Wilson, D.: Case-Based Similarity Assessment: Estimating Adaptability from Experience. Fourteenth National Conference on AI, pp. 674-679, (1997).
9. Lefebvre, D. : Contribution à la modélisation des systèmes dynamiques à évènements discrets pour la commande et la surveillance, HDR, IUT Belfort, France, (2000).
10. Lieber, J., Application of the Revision Theory to Adaptation in Case-Based Reasoning: the Conservative Adaptation, the 7th International Conference on CBR, Belfast, (2007).
11. Rasovska, I., Chebel –Morello, B., Zerhouni, N.: A Case Elaboration Methodology for a Diagnostic and Repair Help. FLAIRS-20 Key West, Florida, May 7-9, (2007).
12. Riesbeck, C.K., Schank, R.C.: Inside Case-Based Reasoning. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc, (1989).
14. Smyth, B., Keane, M.T.: Retrieving Adaptable Cases. The role of adaptation knowledge in case retrieval, in proceedings of EWCBR'93, LNAI 837, éd. Springer (1993).
15. Smyth, B., Keane, M.: Adaptation-guided retrieval: Questioning the similarity assumption in reasoning. *Artificial Intelligence*, number 102, Volume 2, pages 249–293, (1998).
16. Stanfill, C., Waltz, D.: Towards memory-based reasoning. *Communications of the Association for Computing Machinery*, number 29, pages 1213-1228, (1986).